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# ANNUAL PLANTS AT HIGH ALTITUDES IN THE SIERRA NEVADA, CALIFORNIA

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In a previous paper (Went, 1948) some remarks were made about annual plants in the southern Sierra Nevada. It was shown that 75 per cent of them had close relatives in the desert, because 1) the alpine habitat of the southern Sierra is climatologically closely related to the desert habitat, and 2) so many alpine annuals belong to western American endemic genera. From Table 3 in the cited paper it would seem as if therophytes (annual plants) were more developed in the European alpine regions than in the Sierra Nevada. Observations made in 1951 in the Evolution Basin of the Southern Sierra Nevada (just west of Bishop) and in 1952 in the Mt. Banner-Ritter area tend to modify the latter conclusion. At an elevation of exactly 3000 m., about 300 m. below timberline, a total of 36 annual plants was observed (see Table 1). At 3300 m., still 12 annuals were observed, which are marked in the table. There is no doubt in my mind that many more annual species can be found at 3000 m. or above in other localities of the Sierra Nevada, or in other years. It is difficult to use the altitudinal distribution data from Jepson, since they are rather consistently too low. This may be partly due to the fact that many of his figures are based on the northern and central California mountains rather than the southern Sierra Nevada. It also is caused by the necessarily incomplete collection on which his conclusions are based, but perhaps the most important factor is that when the seeds of annuals are present at higher altitudes, they germinate more rarely, and thus these plants are collected only occasionally.

Table 1 gives data which were obtained through perusal of the herbarium of the University of California in Berkeley, Jepson's Manual, and trips into the Sierra Nevada in 1945-1951. In 1945 and 1946 the northeastern part of Yosemite National

Table 1. Altitudinal distribution records (m. above sea level) of 49 obligate, facultative, or occasional annuals in the southern Sierra Nevada.

| Annuals | Altitudinal range according to Jepson | Highest recorded in Herbarium U.C. Alt. | Year | Personal observation 1947 3000 m. or over | 1947 3300 m. or over | 1951 3000 m. or over | 1951 2750 m. or over | 1952 3000 m. or over |
|---|---|---|---|---|---|---|---|---|
| Androsace septentrionalis var. subumbellata | 3500-3900 | 3800 | '33, '37, '37 | | | | | |
| Chenopodium album | not given | | | | | | X | |
| Collinsia parviflora | 760-2600 | | | X | X | X | X | X |
| C. Torreyi | 900-2450 | | | | | | | |
| Collomia linearis | 300-2500 | | | | | | | X |
| Cryptantha glomeriflora | 1800-3100 | 3300 | '46, '50 | | | X | X | X |
| Descurainia pinnata | 400-2600 | | | | | | X | |
| Draba stenoloba | 2100-3600 | | | X | | X | | X |
| Eleocharis acicularis var. bella | not given | 3300 | '31 | | | X | | |
| E. Bolanderi | 1800-2100 | | | | | | | X |
| Epilobium angustifolium | 600-2000 | | | | X | X | | |
| E. minutum | 30-1400 | | | | | X | | X |
| Eriogonum spergulinum | 1500-2750 | | | | | | X | X |
| Galium bifolium | 1500-2450 | | | | | | | X |
| Gayophytum humile | 1000-2450 | | | X | X | X | X | X |
| G. ramosissimum | 1500-3300 | | | | | | | |
| Gilia leptalea | 300-2750 | 2750 | '35 | | | X | X | X |
| Gnaphalium palustre | 3-1200 | 2300 | | | | X | X | |
| Hemizonella minima | 1100-2450 | 2450 | | | | X | X | X |
| Juncus bufonius | not given | | | | | X | | X |
| J. triformis | 60-1900 | (see Hermann) | | X | X | X | X | X |
| Lewisia nevadensis | 2100-3300 | | | | X | ? | ? | |
| Linanthus ciliatus | 100-2450 | 3050 | '35 | | | X | X | |
| L. ciliatus var. neglectus | 1800-2750 | | | | X | X | X | X |
| L. Harknessii | 1500-2100 | 3100 | '37 | | | X | X | X |
| L. montanus | 400-1500 | 2750 | '05 | | | | | |
| L. oblanceolatus | 2600-3000 | 3300 | '49 | | | | | |
| Mimulus Breweri | 1450-3000 | 3300 | '37, '40 | | | ? | | |
| M. coccineus | | 3300 | '37 | | | | | |
| M. deflexus | | 3300 | '42 | | | | | |
| M. densus | | 2750 | '37, '49 | | | | | |
| M. leptaleus | 2100-2450 | 3200 | '43 | | | | | |
| M. mephiticus | 1500-3300 | 3300 | '96 | | | | | X |
| M. montioides | 1800-3300 | 2750 | '42 | | | ? | | ? |
| M. nanus | 1500-3300 | 3300 | '42 | | | | | |
| M. rubellus | 1800-2900 | 3300 | '42 | X | X | X | X | X |
| M. Suksdorfii | | 3500 | '50 | | | | | |
| M. Whitneyii | | 3300 | '37 | | | | | |
| Muhlenbergia filiformis | not given | | | X | X | X | X | X |
| Navarretia Breweri | 1200-2400 | | | | | | | X |
| N. divaricata | 750-1500 | 2100 | | | | | X | X |
| Nemophila spatulata | 1500-2750 | 3200 | '38 | | | X | X | X |
| Orthocarpus lacerus | | | | | | | | X |
| Phacelia Eisenii | 1250-2450 | 3300 | '49 | | | X | X | X |
| P. humilis | 1200-2500 | 2850 | '44 | | | | | |
| P. ramosissima | 60-2750 | 2900 | '46 | | | | | |
| Plagiobothrys Torreyi | 1200-2450 | 2450 | | | | X | | |
| Polygonum Douglasii | 1200-2450 | 3300 | '42 | | X | X | X | X |
| P. imbricatum (Kelloggii) | 1800-3000 | 2900 | '36 | X | X | X | X | X |
| P. minimum | 1200-2100 | 3500 | '37 | | X | X | X | X |
| P. sawatchense | not given | 2700 | '05 | | | | | |
| P. spergulariaeforme | not given | | | | | | | X |
| Saxifraga bryophora | 2450-3400 | | | | X | X | X | X |
| Streptanthus tortuosus | 600-3200 | | | X | | X | X | X |

Park was visited, and at high altitudes (3000 m. or over) no annual plants were observed. In 1947 a limited number of annuals was found near the "Timberline" station of the Carnegie Institution of Washington, in the vicinity of Tioga Pass in Yosemite National Park, at 3000 m. altitude. In 1949 the Kearsarge Pass area, in the eastern part of Kings' Canyon National Park, was visited, and at 3000 m. only *Polygonum imbricatum* was found. Then in 1951 and 1952 an unprecedented development of annuals was found in the Evolution Basin and Agnew Pass areas, in the northernmost end of Kings' River National Park and just south of Yosemite National Park. Most of the observations were made near Colby Meadows, 3000 m., Evolution Meadow, 2750 m., Evolution Lake, 3300 m., and Agnew Pass, 3000 m.

Eighteen species of annuals were observed at a greater altitude than they had been collected previously. Ten were observed at the same altitude as the highest collected previously, and only six were found lower than they have been found before. Therefore it seemed as if 1951 and 1952 were very special years for the growth of annual plants at high altitudes in the southern Sierra Nevada. To get some data concerning prevalence of annuals at certain altitudes in different years, the collections of 28 species, reaching above 2400 m., were counted in the herbarium of the University of California in Berkeley, and they were divided into four altitudinal ranges and recorded according to year of collection. Table 2 shows the data as obtained from the perusal of the herbarium. It was immediately clear that in two years, 1937 and 1942, about half the annuals were collected at or above 3300 m., whereas in all other years only a small percentage, usually under 20 per cent, was collected at those altitudes. This was partly due to intensive collecting at the higher altitudes during those years (Sharsmith in 1937), but when we compare the number of annuals collected at lower altitudes below 3000 m.), we find that about the same numbers were collected per year in 1937 and 1942, as in all other years from 1933 on. Therefore the general collecting in those years was about normal. In 1949 and 1950 collecting of annuals was about evenly spread over the different altitudinal ranges, which was not an indication of relative abundance at higher altitudes; at least my personal recollection of the aspects of the vegetation in the Kearsarge area during 1949 does not indicate any unusual occurrence of annuals at or above 3000 m. Whereas in the 1948 paper is could be concluded from Table 3 that the number of annuals at comparable altitudes (in relation to timberline) is greater in the Alps than in the Sierra Nevada, a closer analysis seems to show just the opposite situation; there are more annuals just below timberline in the southern Sierra Nevada than in the Alps. And the list of Table 1 is far from complete, since it is based on only very limited field

Table 2. Altitudinal distribution of the collections of 28 annual species in the Herbarium of the University of California at Berkeley, separated according to years.

| Years | Altitudinal Range | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3300 m. | | 3000 m. | | 2700 m. | | 2400 m. | |
| | Total annuals per year | Per Cent | Total | Per Cent | Total | Per Cent | Total | Per Cent |
| 1937 and 1942 | 6.0 | 48 | 4.5 | 36 | 1.5 | 12 | 0.5 | 4 |
| 1949 and 1950 | 2.0 | 29 | 1.5 | 21 | 1.5 | 21 | 2.0 | 29 |
| 1933 - 1936; 1938 - 1941; 1943 - 1946. | 0.3 | 10 | 0.7 | 30 | 0.7 | 30 | 0.7 | 30 |

observations and a very incomplete survey of collections made by others. It seems likely that a complete list of annuals occurring at or above 3000 m. in the Sierra Nevada will comprise 60 to 80 species.

There is an interesting fact which can be extracted from Table 1, and that is the enormous altitudinal range of some of these annuals (Table 3). Whereas perennials, trees, and shrubs usually have a rather limited altitudinal range within which they occur, in annuals this range is much wider, because at different altitudes the same sequence of temperatures may occur at different times of the year. Thus the annuals listed may flower in May or June at their lower range, and in July or August at the higher range, and in this way flowering occurs at the same temperature.

Even though plants at different altitudes may be subjected to the same temperatures at some critical stage of their development, at other stages they are necessarily growing under very different conditions, such as different photoperiods. Therefore we can expect to find strong ecotype formation among these annuals, especially among those with the greatest altitudinal distribution range. Those in Table 3 with a range over 3100 m. are: *Eleocharis acicularis* and *Juncus triformis*. Both of these have been separated into a number of varieties, which, in *Juncus triformis,* have been elevated to the rank of species (Hermann, 1950). An altitudinal distribution range between 2700 and 3100 m. is found in: *Collinsia parviflora, Epilobium angustifolium, E. minutum, Gilia leptalea, Gnaphalium palustre, Juncus bufonius, Linanthus ciliatus* and *Phacelia ramosissima.* Among these ten species only *Epilobium* and *Gnaphalium* can be distributed easily over long distances by wind; the distribution of the other species is probably largely by water, and over limited distances only. Therefore we can expect rather extensive differentiation of ecotypes, almost completely separated geographically, in *Collinsia, Gilia, Juncus, Linanthus* and *Phacelia,* and these plants should be excellent material for the study of evolution. Being annuals, a genetical

Table 3. Number of species which have an altitudinal range within the limits shown in the upper row, as taken from Table 1.

| Meters | 0 - 300 | - 700 | - 1100 | - 1500 | - 1900 | - 2300 | - 2700 | - 3100 | - 3500 |
|---|---|---|---|---|---|---|---|---|---|
| No. of species | 0 | 1 | 3 | 4 | 15 | 5 | 3 | 8 | 2 |

analysis of these plants might be feasible, and thus supplement the data collected by Clausen, Keck, and Hiesey on perennials.

For such an evolutionary study it is necessary to make an extensive seed collection of these annuals in different localities, and every botanist is urged to collect seed of any species listed in Table 1 and to send them to the author.

To see whether the climatical conditions in the years 1937, 1942, and 1951 showed parallel deviations from normal, the weather data from five High Sierra meteorological stations were averaged. The monthly average temperature, and total rainfall were plotted and compared with the normal averages. As stations were chosen; Truckee or Soda Springs (2000 m alt.), Twin Lakes or Tamarack (2400 m. alt.), Ellery Lake (2900 m. alt.), Huntington Lake (2150 m. alt.), and Giant Forest (2000 m. alt.). They lay equidistant approximately in a line north-northwest to south-southeast at 100 km. intervals. This gave a good coverage of climatic conditions in the central and southern High Sierras. The data showed no common denominator for the years with high rates of germaination at high altitudes. It is possible that a warmer than average month of May has something to do with it, but there seem to be no correlations with wet or very warm or cold preceding winters. It is evident that only a much more detailed study of the germination conditions near each of the high altitude meteorological stations might produce useful correlations.

The seeds collected in the Evolution Basin and an additional collection from Timberline Station made by Dr. Jens Clausen were laid out to germinate in different temperatures. The seeds which germinated were those treated for several months at 0° or 5° C., and then kept at low temperatures of 10°-6° C. Most readily grew the bulbils of *Saxifraga bryophora;* in some cases more than 50 per cent developed. In a 16-hour photoperiod at 10° C., alternating with a 6° C. nyctotemperature, the rosettes grew large, and inflorescences with a terminal perfect flower and many lateral bulbils developed. Under the same temperature treatment *Collinsia parviflora, Mimulus* species, *Linanthus Harknessii, L. ciliatus neglectus,* and *Juncus bufonius* germinated and grew well; the plants became several times larger than those observed in nature. Of *Nemophila spathulata* and *Gayophytum* each only one seed (per 50) germinated, but both died before anthesis.

SUMMARY

Based on field collections and a herbarium study, it was shown that at least 40, and probably between 60 and 80 species of annuals could be found at altitudes of 3000 m. and over in the southern Sierra Nevada of California. In a few years (1937, 1942, 1951, 1952) there were an exceptional number of annuals at higher altitudes; this could not be correlated with any meteorological peculiarities in those years.

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## NOTES ON MALVACEAE IV. THREE NEW SPECIES AND A NEW COMBINATION

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**Abutilon Carterae** sp. nov. Planta herbacea, ut videtur annua; caulibus usque 0.5 m. altis, validis, densissime albido-lanatis; foliorum laminis usque 20 cm. longis, suborbicularibus, profunde cordatis sinu aperto, subito acuminatis, crenulato-denticulatis, 9-nervatis, valde discoloratis, subtus dense albido-tomentosis; petiolis validis, laminam plerumque subaequantibus; stipulis filiformibus, mox caducis; floribus in paniculam terminalem, elongatam, pauciramosam, apertam dispositis; calycibus fructiferis circa 6 mm. longis, circa dimidiam partem fructus aequantibus, tomentosis, lobis deltoideis, acuminatis; petalis circa 8 mm. longis, patentibus, ochroleucis, obovatis, insigniter venosis, androeceum et stylos multo superantibus; staminibus numerosis, tubo brevi confertis; stylis elongatis; stigmatibus parvis, capitatis; fructibus breviter cylindraceis, truncatis; carpellis 8 vel 9, circa 10 mm. longis, breviter aristatis, villosis, loculicidalibus, plerumque 2- spermis; seminibus deltoideo-reniformibus, circa 2.5 mm. longis, minute lineato-stellulatis.

Plant herbaceous, apparently annual; stems tall (0.5 m. or more), stout (5 mm. in diameter near base), densely white-lanate with very short, partly forked hairs; leaf blades up to 20 cm. long and 17 cm. wide, suborbicular, deeply cordate with an open sinus, abruptly acuminate, crenulate-denticulate, sometimes obscurely trilobate, strongly discolorous, dark green and tomentulose with very short, simple and forked hairs above, densely white-tomentose beneath, 9-nerved from the base, the veins somewhat prominent beneath; petioles